DYNAMIC NETWORK ALLOCATION FOR MOBILE ROUTER

Cross Reference to Related Applications

This invention is related to U.S. Patent Application Serial No. 09/227,396 (Attorney

Docket No. CISCP075), naming Kent K Leung as inventor, and entitled "MOBILE IP MOBILE

ROUTER." That application is incorporated herein by reference in its entirety and for all

purposes.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to Mobile IP network technology. More particularly, the
present invention relates to dynamic network allocation for a Mobile IP mobile router.

2. Description of the Related Art

Mobile IP is a protocol which allows laptop computers or other mobile computer units
(referred to as "Mobile Nodes" herein) to roam between various sub-networks at various
locations -- while maintaining internet and/or WAN connectivity. Without Mobile IP or related
protocol, a Mobile Node would be unable to stay connected while roaming through various sub-
networks. This is because the IP address required for any node to communicate over the internet
is location specific. Each IP address has a field that specifies the particular sub-network on
which the node resides. If a user desires to take a computer which is normally attached to one
node and roam with it so that it passes through different sub-networks, it cannot use its home
base IP address. As a result, a business person traveling across the country cannot merely roam
with his or her computer across geographically disparate network segments or wireless nodes
while remaining connected over the internet. This is not an acceptable state-of-affairs in the age

of portable computational devices.

To address this problem, the Mobile IP protocol has been developed and implemented. An implementation of Mobile IP is described in RFC 2002 of the Network Working Group, C. Perkins, Ed., October 1996. Mobile IP is also described in the text "Mobile IP Unplugged" by J. Solomon, Prentice Hall. Both of these references are incorporated herein by reference in their entireties and for all purposes.

The Mobile IP process and environment are illustrated in Figure 1A. As shown there, a Mobile IP environment 2 includes the internet (or a WAN) 4 over which a Mobile Node 6 can communicate remotely via mediation by a Home Agent 8 and a Foreign Agent 10. Typically, the Home Agent and Foreign Agent are routers or other network connection devices performing appropriate Mobile IP functions as implemented by software, hardware, and/or firmware. A particular Mobile Node (e.g., a laptop computer) plugged into its home network segment connects with the internet through its designated Home Agent. When the Mobile Node roams, it communicates via the internet through an available Foreign Agent. Presumably, there are many Foreign Agents available at geographically disparate locations to allow wide spread internet connection via the Mobile IP protocol. Note that it is also possible for the Mobile Node to register directly with its Home Agent.

As shown in Figure 1A, Mobile Node 6 normally resides on (or is "based at") a network segment 12 which allows its network entities to communicate over the internet 4 through Home Agent 8 (an appropriately configured router denoted R2). Note that Home Agent 8 need not directly connect to the internet. For example, as shown in Figure 1A, it may be connected through another router (a router R1 in this case). Router R1 may, in turn, connect one or more other routers (e.g., a router R3) with the internet.

Now, suppose that Mobile Node 6 is removed from its home base network segment 12 and roams to a remote network segment 14. Network segment 14 may include various other nodes such as a PC 16. The nodes on network segment 14 communicate with the internet through a router which doubles as Foreign Agent 10. Mobile Node 6 may identify Foreign Agent 10 through various solicitations and advertisements which form part of the Mobile IP protocol. When Mobile Node 6 engages with network segment 14, Foreign Agent 10 relays a registration request to Home Agent 8 (as indicated by the dotted line "Registration"). The Home and Foreign Agents may then negotiate the conditions of the Mobile Node's attachment to Foreign Agent 10. For example, the attachment may be limited to a period of time, such as two hours. When the negotiation is successfully completed, Home Agent 8 updates an internal "mobility binding table" which specifies the care-of address (e.g., a collocated care-of address or the Foreign Agent's IP address) in association with the identity of Mobile Node 6. Further, the Foreign Agent 10 updates an internal "visitor table" which specifies the Mobile Node address,

Home Agent address, etc. In effect, the Mobile Node's home base IP address (associated with segment 12) has been shifted to the Foreign Agent's IP address (associated with segment 14).

Now, suppose that Mobile Node 6 wishes to send a message to a corresponding node 18 from its new location. A message from the Mobile Node is then packetized and forwarded through Foreign Agent 10 over the internet 4 and to corresponding node 18 (as indicated by the dotted line "packet from MN") according to a standard internet protocol. If corresponding node 18 wishes to send a message to Mobile Node -- whether in reply to a message from the Mobile Node or for any other reason -- it addresses that message to the IP address of Mobile Node 6 on sub-network 12. The packets of that message are then forwarded over the internet 4 and to router R1 and ultimately to Home Agent 8 as indicated by the dotted line ("packet to MN(1)"). From its mobility binding table, Home Agent 8 recognizes that Mobile Node 6 is no longer attached to network segment 12. It then encapsulates the packets from corresponding node 18 (which are addressed to Mobile Node 6 on network segment 12) according to a Mobile IP protocol and forwards these encapsulated packets to a "care of" address for Mobile Node 6 as shown by the dotted line ("packet to MN(2)"). The care-of address may be, for example, the IP address of Foreign Agent 10. Foreign Agent 10 then strips the encapsulation and forwards the message to Mobile Node 6 on sub-network 14. The packet forwarding mechanism implemented by the Home and Foreign Agents is often referred to as "tunneling."

In addition to providing connectivity to a mobile node, it may be desirable to provide for the mobility of one or more networks moving together, such as on an airplane or a ship. RFC 2002 section 4.5 discusses the possibility of implementing mobile routers.

In one approach suggested in RFC 2002 section 4.5, a Home Agent is configured to have a permanent registration for each fixed node. For instance, a mobile router may support multiple nodes which may be fixed with respect to the mobile router. In order to receive communication from a corresponding node, messages must be routed to the appropriate fixed node. As the RFC suggests, a Home Agent may be configured to have a permanent registration for each fixed node. By way of example, the permanent registration may indicate the mobile router's address as the care-of address. Thus, a separate mapping table may associate the IP address of each of the fixed nodes with the mobile router. However, this is problematic since the mapping table is typically configured while the mobile router is coupled to the Home Agent. In other words, the routing table is static. Suppose a person boards an airplane and wishes to connect a laptop to the airplane's "mobile network" via the mobile router. If a new node is added to the mobile router after the airplane leaves the airport, the IP address of this new node may not be added to the mapping table. As a result, communication cannot be received by this new node via the mobile router. In addition, since the mobile router 20 may accommodate thousands of devices, or nodes, there would potentially be an enormous number of entries to store in such a mapping table for

these nodes. Moreover, such a mapping table may include entries for multiple mobile routers. Accordingly, such a mapping table would consume a substantial amount of memory as well as be cumbersome to search.

FIG. 2 is a block diagram illustrating a system in which a mobile router is implemented. As shown, when a mobile router 202 roams to a first Foreign Agent 204, it registers with its Home Agent 206 so that it may receive packets from a corresponding node 208. When the mobile router 202 subsequently roams to a second Foreign Agent 210, it again registers with its Home Agent 206. In this manner, a device 212 that has connected to the mobile router 202 may communicate via the internet 4 by connecting to a network 214 of the mobile router 202.

Address space is a precious resource. For mobile routers which have one or more associated networks, address space is consumed even more quickly than for individual nodes. More particularly, IP addresses for entire networks rather than single nodes must be allocated. According to current mobile router implementation schemes, the Home Agent is configured with those networks that are connected to the mobile router. Thus, address space is typically allocated statically for entire networks.

An airplane is an exemplary scenario in which a mobile router may be implemented. For instance, each plane may have a mobile router (and therefore many networks) on board to provide Internet connectivity and services. Statically allocating address space to these networks is an efficient mechanism for configuring the Home Agent with the information it needs to forward messages to a mobile router supported by the Home Agent. However, since not all planes may be active (i.e., flying) simultaneously, it would be beneficial to only allocate subnets to active planes.

In view of the above, it would be desirable to have improved techniques for implementing network allocation for a Mobile IP mobile router.

The following claims are pending:

1.   A Home Agent supporting Mobile IP and being capable of allocating one or more networks to a mobile router which registers with the Home Agent, the Home Agent comprising:

a processor; and

a memory, at least one of the processor and the memory being adapted for:

receiving a registration request packet from the mobile router, the registration request packet including a network allocation extension indicating one or more networks being requested by the mobile router from the Home Agent;

allocating the one or more networks to the mobile router corresponding to the network allocation extension of the registration request packet; and

sending a registration reply packet to the mobile router, the registration reply including a network allocation extension identifying the one or more networks allocated to the mobile router.

2.   The Home Agent as recited in claim 1, wherein at least one of the processor and the memory are further adapted for:

authenticating the mobile router prior to allocating the one or more networks to the mobile router and sending the registration reply packet to the mobile router.

3.   The Home Agent as recited in claim 1, wherein the network allocation extension indicates a number of subnets being requested by the mobile router.

4.   The Home Agent as recited in claim 1, wherein the network allocation extension indicates a size of the one or more networks being requested by the mobile router from the Home Agent.

5.   The Home Agent as recited in claim 1, wherein allocating the one or more networks to

the mobile router corresponding to the network allocation extension of the registration request packet comprises:

allocating the one or more networks from a local pool of available networks, the local pool being managed by the Home Agent.

6. The Home Agent as recited in claim 1, wherein allocating the one or more networks to the mobile router corresponding to the network allocation extension of the registration request packet comprises:

allocating the one or more networks from a DHCP server that manages a pool of available networks.

7. The Home Agent as recited in claim 1, wherein allocating the one or more networks to the mobile router corresponding to the network allocation extension of the registration request packet comprises:

allocating the one or more networks from a AAA server that manages a pool of available networks.

8. The Home Agent as recited in claim 1, wherein at least one of the processor and the memory are further adapted for:

updating a routing table to include one or more entries for the one or more networks that are allocated to the mobile router, wherein each entry in the routing table includes a care-of address associated with the one or more networks.

9. The Home Agent as recited in claim 8, wherein at least one of the processor and the memory are further adapted for:

updating the routing table to remove the one or more entries when a lifetime of the mobile router has expired.

10.   The Home Agent as recited in claim 8, wherein at least one of the processor and the memory are further adapted for:

receiving a deregistration request from the mobile router; and

updating the routing table to remove the one or more networks from the routing table.

11.   The Home Agent as recited in claim 8, wherein at least one of the processor and the memory are further adapted for:

receiving a deregistration request from the mobile router; and

updating the routing table to remove the one or more entries from the routing table.

12.   The Home Agent as recited in claim 1, wherein at least one of the processor and the memory are further adapted for:

updating a mobility binding table to associate the mobile router with a care-of address.

13.   The Home Agent as recited in claim 12, wherein at least one of the processor and the memory are further adapted for:

updating the mobility binding table to remove the association between the mobile router and the care-of address when a lifetime of the mobile router has expired.

14.   The Home Agent as recited in claim 8, wherein at least one of the processor and the memory are further adapted for:

receiving a deregistration request from the mobile router; and

updating the mobility binding table to remove the association between the mobile router and the care-of address.

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15. The Home Agent as recited in claim 1, wherein at least one of the processor and the memory are further adapted for:

deallocating the one or more networks previously allocated to the mobile router when a lifetime of the mobile router has expired.

16. The Home Agent as recited in claim 15, wherein deallocating the one or more networks previously allocated to the mobile router comprises:

replacing the one or more networks to a pool of available networks.

17. The Home Agent as recited in claim 1, wherein at least one of the processor and the memory are further adapted for:

receiving a deregistration request from the mobile router; and

deallocating the one or more networks previously allocated to the mobile router.

18. The Home Agent as recited in claim 17, wherein deallocating the one or more networks previously allocated to the mobile router comprises:

replacing the one or more networks to a pool of available networks.

19. The Home Agent as recited in claim 17, wherein at least one of the processor and the memory are further adapted for:

sending a deregistration reply to the mobile router.

20. A mobile router supporting Mobile IP and being capable of requesting one or more

networks during registration with a Home Agent, the mobile router comprising:

a processor; and

a memory, at least one of the processor and the memory being adapted for:

composing a registration request packet, the registration request packet including a network allocation extension indicating one or more networks being requested by the mobile router from a Home Agent;

sending the registration request packet to the Home Agent; and

receiving a registration reply packet from the Home Agent, the registration reply including a network allocation extension identifying one or more networks allocated to the mobile router by the Home Agent.

21.   The mobile router as recited in claim 20, wherein the network allocation extension indicates a number of subnets being requested by the mobile router.

22.   The mobile router as recited in claim 20, wherein the network allocation extension indicates a size of the one or more networks being requested by the mobile router from the Home Agent.

23.   The mobile router as recited in claim 20, wherein at least one of the processor and the memory are further adapted for:

detecting a Foreign Agent prior to composing and sending the registration request packet to the Home Agent.

24.   The mobile router as recited in claim 20, wherein at least one of the processor and the memory are further adapted for:

selecting from the one or more networks allocated to the mobile router by the Home Agent an IP address; and

configuring an interface of the mobile router with the IP address such that a network

coupled to the interface is identified by the IP address.

25.   The mobile router as recited in claim 24, wherein at least one of the processor and the memory are further adapted for:

deconfiguring the interface of the mobile router such that the interface is not identified by the IP address.

26.   The mobile router as recited in claim 25, wherein deconfiguring the interface is performed when a lifetime of the mobile router has expired.

27.   The mobile router as recited in claim 25, wherein at least one of the processor and the memory are further adapted for:

sending a deregistration request to the Home Agent prior to deconfiguring the interface of the mobile router.

28.   The mobile router as recited in claim 20, wherein at least one of the processor and the memory are further adapted for:

adding the one or more networks identified in the network allocation extension to a private DHCP pool available to the mobile router.

29.   The mobile router as recited in claim 28, wherein at least one of the processor and the memory are further adapted for:

removing the one or more networks from the private DHCP pool available to the mobile router.

30.   The mobile router as recited in claim 29, wherein removing the one or more networks

from the private DHCP pool available to the mobile router is performed when a lifetime of the mobile router has expired.

31.   The mobile router as recited in claim 29, wherein at least one of the processor and the memory are further adapted for:

        sending a deregistration request to the Home Agent prior to removing the one or more networks from the private DHCP pool available to the mobile router.

32.   The mobile router as recited in claim 28, wherein at least one of the processor and the memory are further adapted for:

        updating a registration table to indicate a lifetime granted during registration of the mobile router with the Home Agent.

33.   The mobile router as recited in claim 32, wherein at least one of the processor and the memory are further adapted for:

        deleting an entry from the registration table when the lifetime has expired.

34.   The mobile router as recited in claim 20, wherein at least one of the processor and the memory are further adapted for:

        sending a deregistration request to the Home Agent.

35.   The mobile router as recited in claim 34, wherein at least one of the processor and the memory are further adapted for:

        receiving a deregistration reply from the Home Agent.

36.   A computer readable medium for implementing a Home Agent supporting Mobile IP, the Home Agent being capable of allocating one or more networks to a mobile router which registers with the Home Agent, the computer readable medium comprising the following instructions:

instructions for receiving a registration request packet from the mobile router, the registration request packet including a network allocation extension indicating one or more networks being requested by the mobile router from the Home Agent;

instructions for allocating the one or more networks to the mobile router corresponding to the network allocation extension of the registration request packet; and

instructions for sending a registration reply packet to the mobile router, the registration reply including a network allocation extension identifying the one or more networks allocated to the mobile router.

37.   A Home Agent supporting Mobile IP, the Home Agent being capable of allocating one or more networks to a mobile router which registers with the Home Agent, comprising:

means for receiving a registration request packet from the mobile router, the registration request packet including a network allocation extension indicating one or more networks being requested by the mobile router from the Home Agent;

means for allocating the one or more networks to the mobile router corresponding to the network allocation extension of the registration request packet; and

means for sending a registration reply packet to the mobile router, the registration reply including a network allocation extension identifying the one or more networks allocated to the mobile router.

38.   In a Home Agent supporting Mobile IP, a method of allocating one or more networks to a mobile router which registers with the Home Agent, comprising:

receiving a registration request packet from the mobile router, the registration request packet including a network allocation extension indicating one or more networks being requested by the mobile router from the Home Agent;

allocating the one or more networks to the mobile router corresponding to the network allocation extension of the registration request packet; and

sending a registration reply packet to the mobile router, the registration reply including a network allocation extension identifying the one or more networks allocated to the mobile router.

39.   In a mobile router supporting Mobile IP, a method of requesting one or more networks during registration with a Home Agent, comprising:

composing a registration request packet, the registration request packet including a network allocation extension indicating one or more networks being requested by the mobile router from a Home Agent;

sending the registration request packet to the Home Agent; and

receiving a registration reply packet from the Home Agent, the registration reply including a network allocation extension identifying one or more networks allocated to the mobile router by the Home Agent.

40.   The method as recited in claim 39, wherein the network allocation extension indicates a number of subnets being requested by the mobile router.

41.   The method as recited in claim 39, wherein the network allocation extension indicates a size of the one or more networks being requested by the mobile router from the Home Agent.

42.   The method as recited in claim 39, wherein at least one of the processor and the memory are further adapted for:

detecting a Foreign Agent prior to composing and sending the registration request packet to the Home Agent.

43.   The method as recited in claim 39, wherein at least one of the processor and the memory are further adapted for:

selecting from the one or more networks allocated to the mobile router by the Home Agent an IP address; and

configuring an interface of the mobile router with the IP address such that a network coupled to the interface is identified by the IP address.

44.   The method as recited in claim 43, further comprising:

deconfiguring the interface of the mobile router such that the interface is not identified by the IP address.

45.   The method as recited in claim 44, wherein deconfiguring the interface is performed when a lifetime of the mobile router has expired.

46.   The method as recited in claim 44, further comprising:

sending a deregistration request to the Home Agent prior to deconfiguring the interface of the mobile router.

47.   The method as recited in claim 39, further comprising:

adding the one or more networks identified in the network allocation extension to a private DHCP pool available to the mobile router.

48.   The method as recited in claim 47, further comprising:

removing the one or more networks from the private DHCP pool available to the mobile router.

49.   The method as recited in claim 48, wherein removing the one or more networks from the private DHCP pool available to the mobile router is performed when a lifetime of the mobile router has expired.

50.   The method as recited in claim 48, further comprising:

sending a deregistration request to the Home Agent prior to removing the one or more networks from the private DHCP pool available to the mobile router.

51.   The method as recited in claim 47, further comprising:

updating a registration table to indicate a lifetime granted during registration of the mobile router with the Home Agent.

52.   The method as recited in claim 51, further comprising:

deleting an entry from the registration table when the lifetime has expired.

53.   The method as recited in claim 39, further comprising:

sending a deregistration request to the Home Agent.

54.   The method as recited in claim 53, further comprising:

receiving a deregistration reply from the Home Agent.

55.   A computer-readable medium storing thereon computer-readable instructions for requesting one or more networks during registration with a Home Agent in a mobile router supporting Mobile IP, comprising:

instructions for composing a registration request packet, the registration request packet including a network allocation extension indicating one or more networks being requested by the mobile router from a Home Agent;

instructions for sending the registration request packet to the Home Agent; and

instructions for receiving a registration reply packet from the Home Agent, the registration reply including a network allocation extension identifying one or more networks allocated to the mobile router by the Home Agent.

56. The computer-readable medium as recited in claim 55, wherein the network allocation extension indicates a number of subnets being requested by the mobile router.

57. The computer-readable medium method as recited in claim 55, wherein the network allocation extension indicates a size of the one or more networks being requested by the mobile router from the Home Agent.

58. The computer-readable medium method as recited in claim 55, wherein at least one of the processor and the memory are further adapted for:

detecting a Foreign Agent prior to composing and sending the registration request packet to the Home Agent.

59. The computer-readable medium method as recited in claim 55, wherein at least one of the processor and the memory are further adapted for:

selecting from the one or more networks allocated to the mobile router by the Home Agent an IP address; and

configuring an interface of the mobile router with the IP address such that a network coupled to the interface is identified by the IP address.

60. The computer-readable medium method as recited in claim 59, further comprising:

deconfiguring the interface of the mobile router such that the interface is not identified by the IP address.

61. The computer-readable medium method as recited in claim 60, wherein deconfiguring the

interface is performed when a lifetime of the mobile router has expired.

62.   The computer-readable medium method as recited in claim 60, further comprising:

sending a deregistration request to the Home Agent prior to deconfiguring the interface of the mobile router.

63.   The computer-readable medium method as recited in claim 55, further comprising:

adding the one or more networks identified in the network allocation extension to a private DHCP pool available to the mobile router.

64.   The computer-readable medium as recited in claim 63, further comprising:

removing the one or more networks from the private DHCP pool available to the mobile router.

65.   The computer-readable medium as recited in claim 64, wherein removing the one or more networks from the private DHCP pool available to the mobile router is performed when a lifetime of the mobile router has expired.

66.   The computer-readable medium as recited in claim 64, further comprising:

sending a deregistration request to the Home Agent prior to removing the one or more networks from the private DHCP pool available to the mobile router.

67.   The computer-readable medium as recited in claim 63, further comprising:

updating a registration table to indicate a lifetime granted during registration of the mobile router with the Home Agent.

68.   The computer-readable medium as recited in claim 67, further comprising:

deleting an entry from the registration table when the lifetime has expired.

69.   The computer-readable medium as recited in claim 55, further comprising:

sending a deregistration request to the Home Agent.

70.   The computer-readable medium as recited in claim 69, further comprising:

receiving a deregistration reply from the Home Agent.

71.   A mobile router supporting Mobile IP and adapted for requesting one or more networks during registration with a Home Agent, comprising:

means for composing a registration request packet, the registration request packet including a network allocation extension indicating one or more networks being requested by the mobile router from a Home Agent;

means for sending the registration request packet to the Home Agent; and

means for receiving a registration reply packet from the Home Agent, the registration reply including a network allocation extension identifying one or more networks allocated to the mobile router by the Home Agent.